

## PROJECT ADMINISTRATION DATA SHEET

☒ ORIGINAL ☐ REVISION NO. \_\_\_\_\_Project No. A-3042 DATE 9/4/81Project Director: R. W. Rice ~~Scientific Atlanta~~ Lab ECSL/CSDSponsor: Scientific AtlantaType Agreement: Std. Research AgreementAward Period: From 9/4/81 To 11/4/81 (Performance) 11/4/81 (Reports)Sponsor Amount: \$28,878 12/14/81 12/14/81 Contracted through:Cost Sharing: N/A GTRI/GMXTitle: RF MODEM Design and Development

## ADMINISTRATIVE DATA

OCA Contact Faith G. Costello

## 1) Sponsor Technical Contact:

SAME As No. 2

## 2) Sponsor Admin/Contractual Matters:

Mr. Ken McLauren Glen DavisScientific Atlanta4300 NE Expressway Box 105038Atlanta, GA 30340Defense Priority Rating: N/ASecurity Classification: N/A

## RESTRICTIONS

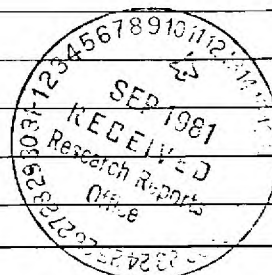
See Attached N/A Supplemental Information Sheet for Additional Requirements.

Travel: Foreign travel must have prior approval – Contact OCA in each case. Domestic travel requires sponsor approval where total will exceed greater of \$500 or 125% of approved proposal budget category.

Equipment: Title vests with Sponsor; however, none proposed.

## COMMENTS:

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SPONSORED PROJECT TERMINATION SHEETDate 1/4/82

Project Title: RF MODEM Design and Development

Project No: A-3042

Project Director: R. W. Rice

Sponsor: Scientific Atlanta

Effective Termination Date: 12/4/81Clearance of Accounting Charges: 12/4/81

Grant/Contract Closeout Actions Remaining:

- ☒ Final Invoice and Closing Documents
- ☐ Final Fiscal Report
- ☐ Final Report of Inventions
- ☐ Govt. Property Inventory & Related Certificate
- ☐ Classified Material Certificate
- ☐ Other \_\_\_\_\_

Assigned to: ECSL/CSD ~~(School/Laboratory)~~COPIES TO:

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Project File  
Other \_\_\_\_\_

A 3042



# Georgia Institute of Technology

ENGINEERING EXPERIMENT STATION

ATLANTA, GEORGIA 30332

2 October 1981

Scientific-Atlanta  
Energy Management Products Division  
Attn: Mr. Ken McLaurin  
Box 105038  
Atlanta, GA 30348

Subject: Monthly Report No. 1 on  
RF Modem Development (A-3042) Project  
covering the period September 3, 1981 to October 3, 1981

Dear Mr. McLaurin:

During the period covered by this report the following actions have been taken:

- (1) various receiver modules, i.e., demodulators, IF filters, mixers, and oscillators, have been designed, fabricated, and tested.
- (2) a complete breadboard of the 107 MHz receiver has been constructed and tested,
- (3) a PC board layout for the 107 MHz receiver has been produced along with the etched boards,
- (4) fabrication of a PC board version of the 107 MHz receiver has begun, and
- (5) design, fabrication and testing of various transmitter modules, i.e., FSK modulators, crystal switchers, digitally controlled attenuators, and power amplifiers, has begun.

At present, we are approximately one week behind schedule. This delay is primarily attributable to delays on S-A's part in accurately defining the PC board format for the 107 MHz receiver and the 19 MHz transmitter. Additionally, S-A has recently informed Georgia Tech that the required sensitivity of the 107 MHz receiver should be approximately 34 dB greater than originally defined. The impact of this change cannot be evaluated until the present 107 MHz receiver is fully tested.

Scientific-Atlanta  
2 October 1981  
Page Two

Scientific-Atlanta has also requested that an amplified and filtered AGC voltage be provided as an output on the 19 MHz receiver. It is not anticipated that it will require a significant redesign effort on the demodulator stage; however, it will most likely significantly alter the PC board layout of the demodulator stage.

During the next work period, Georgia Tech's efforts will be directed toward the following:

- (1) complete fabrication and testing of the 107 MHz receiver with design modifications as necessary to meet the increased sensitivity requirement,
- (2) complete design, fabrication and testing of the 19 MHz transmitter with the added digitally controlled attenuator,
- (3) design, fabricate, and test a 19 MHz receiver with the added AGC circuitry, and
- (4) design, fabricate, and test a 107 MHz transmitter.

Respectfully submitted,

Robert W. Rice, Ph.D.  
Senior Research Engineer

RWR:gh

Approved:

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R. W. Moss, Chief  
Communications Systems Division

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Georgia Institute of Technology  
ENGINEERING EXPERIMENT STATION  
ATLANTA, GEORGIA 30332

November 3, 1981

Scientific-Atlanta  
Energy Management Products Division  
Attn: Mr. Glen Davis  
Box 105038  
Atlanta, Georgia 30348

Subject: Monthly Report No. 2 on  
RF Modem Development (A-3042) Project  
covering the period  
October 3, 1981 to November 3, 1981

Dear Mr. Davis:

During the period covered by this report the following actions have been taken:

- (1) Work has continued on the 107 MHz receiver and the 19 MHz transmitter.
- (2) The sensitivity of the 107 MHz receiver has been increased to meet the current objective of -40 dBmV.
- (3) A new layout using a double-sided board and substantial amounts of ground plane area has been produced with the result that the local oscillation feed through has been reduced to -50 dBmV with a design goal of -60 dBmV. The inclusion of additional ground plane area and the possible use of shields will be the next step taken to reduce the local oscillation feed-through problem.
- (4) As requested by S-A, a digitally controlled attenuator has been designed, implemented and included in the 19 MHz transmitter.

- (5) As requested by S-A, transistor switches have been included in various 19 MHz transmitter stages to reduce the current drain when the transmitter is not active.
- (6) The design and fabrication of the 19 MHz receiver and the 107 MHz transmitter has begun.
- (7) The 107 MHz transmitter will be very similar in design to the 19 MHz transmitter with the following exceptions: (a) it will operate on one RF channel only, (b) it will not include a digital attenuator, and (c) it will be designed for a stand-alone board (no receiver present on the same board),
- (8) The 19 MHz receiver will be very similar in design to the 107 MHz receiver with the following exceptions: (a) it will have a digitally controlled local oscillator which selects one of two possible receiver channels, (b) as requested by S-A, it will have an analog output which is proportional to the received signal level, and (c) it will be designed for a stand-alone board (no transmitter present on the same board).

Due to the various design changes and development problems encountered, the project is approximately three (3) weeks behind schedule, and as a result of my telephone conversations with you, it is my understanding that extension of the project termination date for approximately three weeks is acceptable to S-A and that S-A will promptly notify the GTRI contracts office of this change. Additionally, I have informed you that our current budget may contain sufficient funds to cover the extended period; however, the adequacy of the current funding will not be accurately known until our budget reports are available (typically around the tenth of the month) and we can access the results of the current efforts to reduce local oscillator feed-through.

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November 3, 1981  
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Assuming the time extension and possibly additional funding, we will continue to work on completing the design, development, and testing of the four modules which are a part of this project.

Respectfully submitted.

Robert W. Rice, Ph.D.  
Senior Research Engineer

RWR:ae

Approved:

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R. W. Moss, Chief  
Communications Systems Division

DESIGN AND DEVELOPMENT OF  
RF MODEMS FOR HIGH SPEED  
BI-DIRECTIONAL DATA TRANSMISSION  
ON CATV SYSTEMS

By

R.W. Rice, Project Director  
W.B. Warren

December, 1981

Prepared for

ENERGY MANAGEMENT PRODUCTS DIVISION  
Scientific-Atlanta

ENGINEERING EXPERIMENT STATION  
Georgia Institute of Technology  
Atlanta, Georgia 30332

Project A-3042



## FOREWORD

This report was prepared by the Communications Systems Division of the Electronics and Computer Systems Laboratory at the Georgia Institute of Technology. The work described was performed under the general supervision of Mr. F.L. Cain, Director of the Georgia Tech Electronics and Computer Systems Laboratory, and Mr. R.W. Moss, Chief of the Communications Systems Division. The project was directed by Dr. R.W. Rice, and Mr. W.B. Warren also contributed significantly to the work presented here. Appreciation is expressed to Mr. James Worsham and Mr. Mark Wilson for their contributions in circuit fabrication.

At Scientific-Atlanta, work by Mr. Glen Davis and Mr. Ken McLauren is also acknowledged. The report preparation efforts of Ms. Ann Evans are appreciated.

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## 1. Introduction

This report summarizes the design and development of RF modem equipment for Scientific-Atlanta. In particular, the Georgia Tech Engineering Experiment Station designed and produced prototypes of the following items:

- (1) a 107 MHz FSK receiver,
- (2) a 19 MHz FSK transmitter,
- (3) a 19 MHz FSK receiver, and
- (4) a 107 MHz FSK transmitter.

The required operating features of each of these devices are discussed in following sections and schematics and parts lists are provided for each unit.

## 2. The 107 MHz FSK Receiver

The operating requirements for the 107 MHz receiver are as follows:

- (1) a sensitivity of -32 dBmV (25 microvolts) defined as the point at which the amplitude of the detected audio drops 3 dB, and
- (2) a conducted spurious emission level of at least -50 dBmV as measured at the cable connection of receiver.

Figure 1 presents the circuit which has been developed to serve as the 107 MHz receiver, and a parts list for this circuit is provided in Table 1.

The measured performance of the prototype circuit delivered to S/A was as follows:

- (1) sensitivity: -30.5 dBmV (30 microvolts)
- (2) spurious emissions: -37 dBmV @ 32.2666 MHz  
not measurable @ 64.5332 MHz  
-23 dBmV @ 96.7998 MHz.

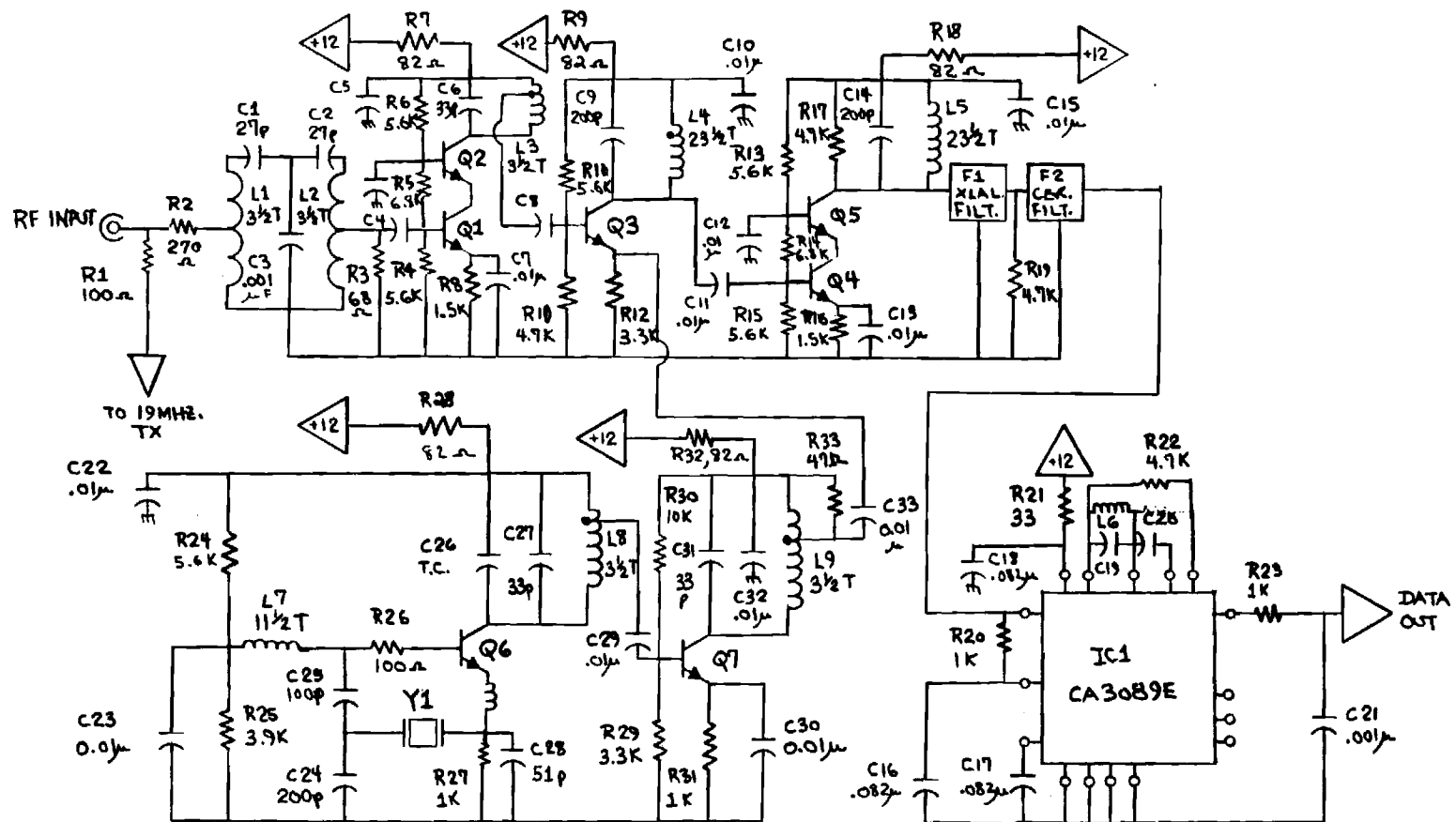


Figure 1. Schematic of 107 MHz Receiver.

TABLE 1

## 107 MHz RECEIVER PARTS LIST

<u>PART NUMBER</u>	<u>PART DESCRIPTION</u>
RESISTORS (All Resistors are Carbon Film)	
R1	1/4W, 100 Ohm
R2	1/4W, 220 Ohm
R3	1/4W, 68 Ohm
R4	1/4W, 5.6 K
R5	1/4W, 6.8 K
R6	1/4W, 5.6 K
R7	1/4W, 82 Ohm
R8	1/4W, 1.5 K
R9	1/4W, 82 Ohm
R10	1/4W, 5.6 K
R11	1/4W, 4.7 K
R12	1/4W, 3.3 K
R13	1/4W, 5.6 K
R14	1/4W, 6.8 K
R15	1/4W, 5.6 K
R16	1/4W, 1.5 K
R17	1/4W, 4.7 K
R18	1/4W, 82 Ohm
R19	1/4W, 4.7 K
R20	1/4W, 1 K
R21	1/4W, 33 Ohm
R22	1/4W, 4.7 K
R23	1/4W, 1 K
R24	1/4W, 5.6 K
R25	1/4W, 3.9 K
R26	1/4W, 100 Ohm
R27	1/4W, 1 K
R28	1/4W, 82 Ohm
R29	1/4W, 3.3 K

TABLE 1 - Continued

<u>PART NUMBER</u>	<u>PART DESCRIPTION</u>
RESISTORS	
R30	1/4W, 10 K
R31	1/4W, 1 K
R32	1/4W, 82 Ohm
R33	1/4W, 47 Ohm
CAPACITORS (All Ceramic and Silver Mica are 50 VDC)	
C1	50 V, 27 pF, Silver Mica
C2	50 V, 27 pF, Silver Mica
C3	50 V, 0.001 Microfarad, Ceramic
C4	50 V, 0.01 Microfarad, Ceramic
C5	50 V, 0.01 Microfarad, Ceramic
C6	50 V, 33 pF, Silver Mica
C7	50 V, 0.01 Microfarad, Ceramic
C8	50 V, 10 pF, Ceramic
C9	50 V, 200 pF, Silver Mica
C10	50 V, 0.01 Microfarad, Ceramic
C11	50 V, 0.01 Microfarad, Ceramic
C12	50 V, 0.01 Microfarad, Ceramic
C13	50 V, 0.01 Microfarad, Ceramic
C14	50 V, 200 pF, Silver Mica
C15	50 V, 0.01 Microfarad, Ceramic
C16	50 V, 0.082 Microfarad, Ceramic
C17	50 V, 0.082 Microfarad, Ceramic
C18	50 V, 0.082 Microfarad, Ceramic
C19	50 V, 200 pF, Silver Mica
C20	50 V, 1 pF, Silver Mica
C21	50 V, 0.01 Microfarad, Ceramic

TABLE 1 - Continued

<u>PART NUMBER</u>	<u>PART DESCRIPTION</u>
CAPACITORS	
C22	50 V, 0.001 Microfarad, Ceramic
C23	50 V, 0.01 Microfarad, Ceramic
C24	50 V, 200 pF, Silver Mica
C25	50 V, 100 pF, Silver Mica
C26	Temperature Compensation as Required
C27	50 V, 33 pF, Silver Mica
C28	50 V, 51 pF, Silver Mica
C29	50 V, 0.01 Microfarad, Ceramic
C30	50V, 0.01 Microfarad, Ceramic
C31	50 V, 33 pF, Silver Mica
C32	50 V, 0.01 Microfarad, Ceramic
C33	50 V, 0.01 Microfarad, Ceramic
INDUCTORS	
L1	3-1/2 Turn Coil
L2	3-1/2 Turn Coil
L3	3-1/2 Turn Coil
L4	23-1/2 Turn Coil
L5	23-1/2 Turn Coil
L7	11-1/2 Turn Coil
L8	3-1/2 Turn Coil
L9	3-1/2 Turn Coil

TABLE 1 - Continued

<u>PART NUMBER</u>	<u>PART DESCRIPTION</u>
TRANSISTORS	
Q1	2N5179
Q2	2N5179
Q3	2N5179
Q4	2N5179
Q5	2N5179
Q6	2N5179
Q7	2N5179
INTEGRATED CIRCUITS	
IC1	CA3089E
F1	2 Pole Crystal Filter, 10.7 MHz Center Frequency, 30 kHz Bandwidth
F2	Ceramic Filter, 10.7 MHz Center Frequency, 200 kHz Bandwidth
CRYSTALS	
Y1	32.2666 MHz, Series Resonant, Third Over Tone Crystal



Note that the spurious emission levels are significantly higher than the design goals; however, it was observed that comparable levels were observed when the cable normally used to connect the receiver input to the spectrum analyzer input was disconnected from the receiver input but left in the immediate vicinity of the receiver. This strongly suggests that much of the observed emissions is radiated rather than conducted. As discussed with S/A personnel, we believe that the radiated emission level can be significantly reduced by placing a metallic shield around at least the local oscillator stage of the receiver. Provision has been made in the printed circuit board for such a shield should the field test currently being conducted by S/A demonstrate that further reduction of the spurious emissions is required.

### 3. The 19 MHz FSK Transmitter

The operating requirements for the 19 MHz transmitter are as follows:

- (1) an output level of +50 dBmV,
- (2) a remotely controllable attenuator to adjust the output level by up to 20 dB,
- (3) a conducted spurious emission level 60 dB below the output of the transmitter, and
- (4) a signal bandwidth of 50 kHz.

Figure 2 presents the circuit which has been developed to serve as the 19 MHz receiver, and a parts list for this circuit is provided in Table 2.

The measured performance of the prototype circuit delivered to S/A was as follows:

- (1) output level: +60 dBmV
- (2) the output is adjustable over a 29 dB range in 2.5 dB steps
- (3) the conducted spurious emissions observed were as follows:
  - 63 dB below carrier at 14 MHz
  - 65 dB below carrier at 57 MHz

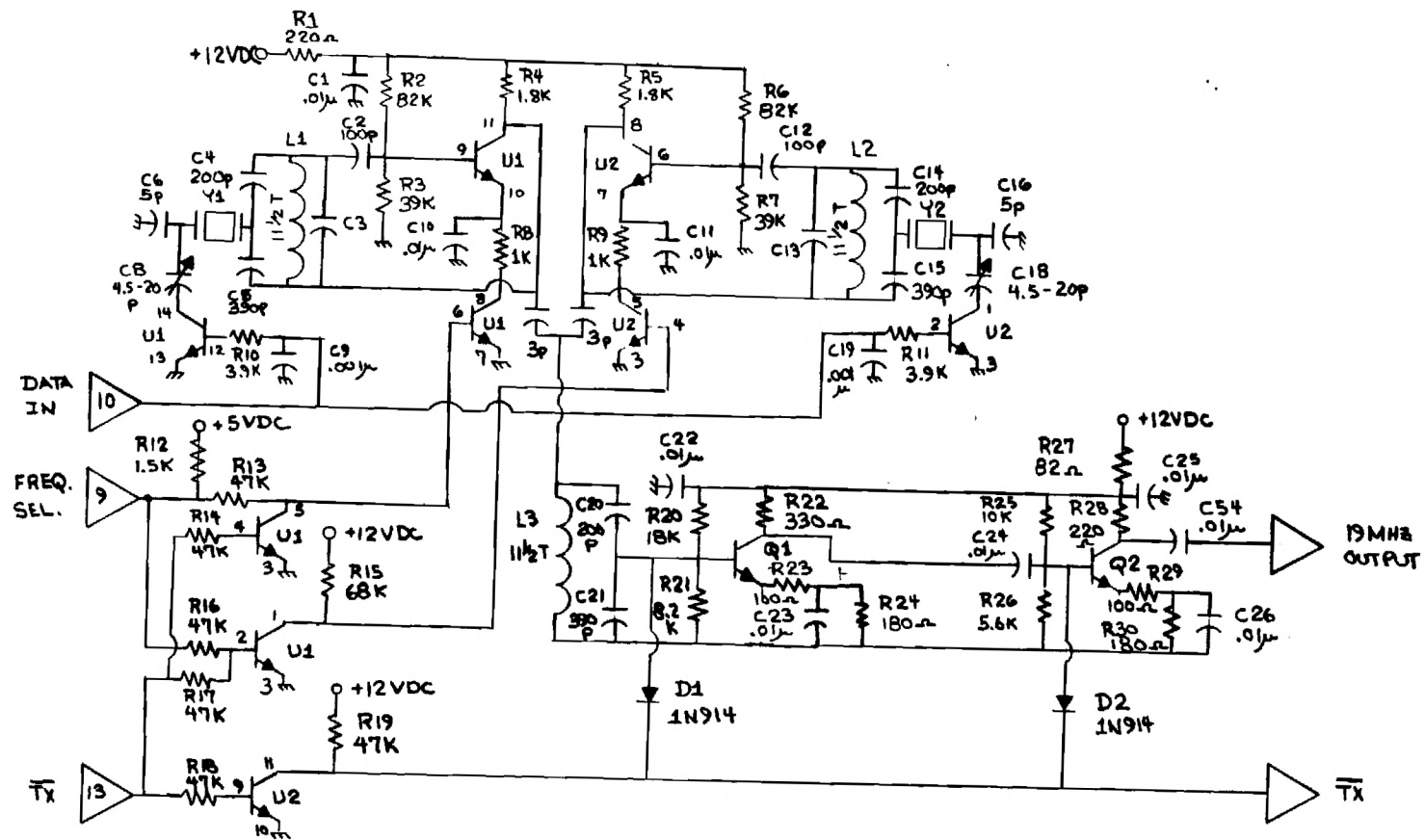


Figure 2. Schematic of 19 MHz Transmitter.

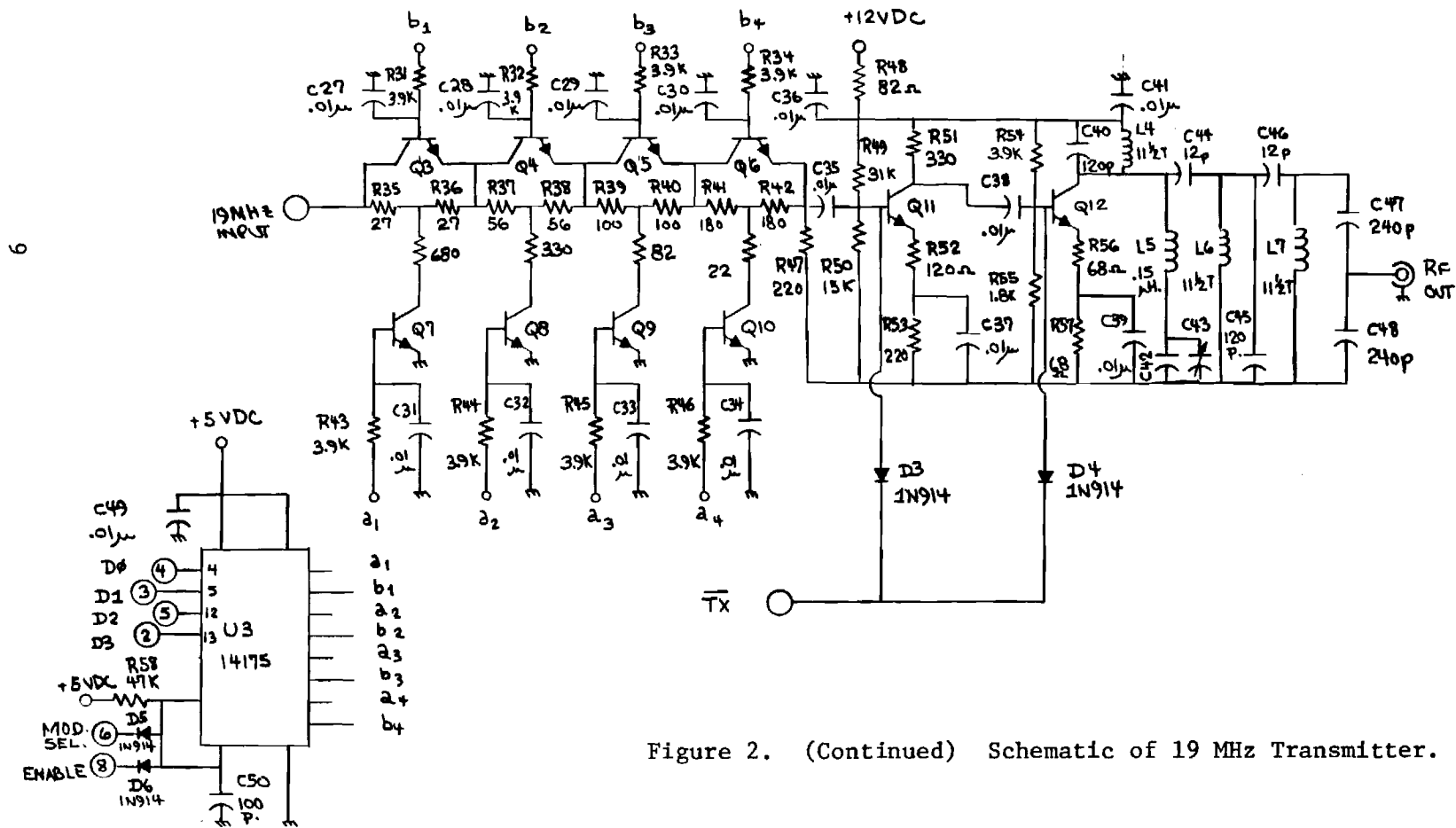


Figure 2. (Continued) Schematic of 19 MHz Transmitter.

TABLE 2

## 19 MHz TRANSMITTER PARTS LIST

<u>PART NUMBER</u>	<u>PART DESCRIPTION</u>
RESISTORS (All Resistors are Carbon Film Type)	
R1	1/4W, 220 Ohm
R2	1/4W, 82 K
R3	1/4W, 39 K
R4	1/4W, 1.8 K
R5	1/4W, 1.8 K
R6	1/4W, 82 K
R7	1/4W, 39 K
R8	1/4W, 1 K
R9	1/4W, 1 K
R10	1/4W, 3.9 K
R11	1/4W, 3.9 K
R12	1/4W, 1.5 K
R13	1/4W, 47 K
R14	1/4W, 47 K
R15	1/4W, 68 K
R16	1/4W, 47 K
R17	1/4W, 47 K
R18	1/4W, 47 K
R19	1/4W, 47 K
R20	1/4W, 18 K
R21	1/4W, 8.2 K
R22	1/4W, 330 Ohm
R23	1/4W, 100 Ohm
R24	1/4W, 180 Ohm
R25	1/4W, 10 K
R26	1/4W, 5.6 K
R27	1/4W, 82 Ohm
R28	1/4W, 220 Ohm
R29	1/4W, 100 Ohm

TABLE 2 - Continued

<u>PART NUMBER</u>	<u>PART DESCRIPTION</u>
RESISTORS	
R30	1/4W, 180 Ohm
R31	1/4W, 3.9 K
R32	1/4W, 3.9 K
R33	1/4W, 3.9 K
R34	1/4W, 3.9 K
R35	1/4W, 27 Ohm
R36	1/4W, 27 Ohm
R37	1/4W, 56 Ohm
R38	1/4W, 56 Ohm
R39	1/4W, 100 Ohm
R40	1/4W, 100 Ohm
R41	1/4W, 180 Ohm
R42	1/4W, 180 Ohm
R43	1/4W, 3.9 K
R44	1/4W, 3.9 K
R45	1/4W, 3.9 K
R46	1/4W, 3.9 K
R47	1/4W, 220 Ohm
R48	1/4W, 82 Ohm
R49	1/4W, 39 K
R50	1/4W, 15 K
R51	1/4W, 330 Ohm
R52	1/4W, 120 Ohm
R53	1/4W, 220 Ohm
R54	1/4W, 3.9 K
R55	1/4W, 1.8 K
R56	1/4W, 68 Ohm
R57	1/4W, 68 Ohm
R58	1/4W, 47 K

TABLE 2 - Continued

<u>PART NUMBER</u>	<u>PART DESCRIPTION</u>
CAPACITORS (All Ceramic and Silver Mica are 50 V DC)	
C1	.01 Microfarad Ceramic
C2	100 pF Silver Mica
C3	Temperature Compensating
C4	200 pF Silver Mica
C5	390 pF Silver Mica
C6	5 pF Silver Mica
C8	4.5-20 pF Trimmer
C9	.001 Microfarad Ceramic
C10	.01 Microfarad Ceramic
C11	.01 Microfarad Ceramic
C12	100 pF Silver Mica
C13	Temperature Compensating
C14	200 pF Silver Mica
C15	390 pF Silver Mica
C16	5 pF Silver Mica
C18	4.5-20 pF Trimmer
C19	.001 Microfarad Ceramic
C20	200 pF Silver Mica
C21	390 Silver Mica
C22	.01 Microfarad Ceramic
C23	.01 Microfarad Ceramic
C24	.01 Microfarad Ceramic
C25	.01 Microfarad Ceramic
C26	.01 Microfarad Ceramic
C27	.01 Microfarad Ceramic
C28	.01 Microfarad Ceramic
C29	.01 Microfarad Ceramic
C30	.01 Microfarad Ceramic
C31	.01 Microfarad Ceramic

TABLE 2 - Continued

<u>PART NUMBER</u>	<u>PART DESCRIPTION</u>
CAPACITORS (All Ceramic and Silver Mica are 50 V DC)	
C32	.01 Microfarad Ceramic
C33	.01 Microfarad Ceramic
C34	.01 Microfarad Ceramic
C35	.01 Microfarad Ceramic
C36	.01 Microfarad Ceramic
C37	.01 Microfarad Ceramic
C38	.01 Microfarad Ceramic
C39	.01 Microfarad Ceramic
C40	120 pF Silver Mica
C41	.01 Microfarad Ceramic
C42	47 pF Silver Mica
C43	3.5-13 pF Trimmer
C44	12 pF Silver Mica
C45	120 pF Silver Mica
C46	12 pF Silver Mica
C47	240 pF Silver Mica
C48	240 pF Silver Mica
C49	.01 Microfarad Ceramic
C50	100 pF Silver Mica
C51	.01 Microfarad Ceramic
C52	10 Microfarad Electrolytic 25 V
C53	10 Microfarad Electrolytic 25 V
C54	.01 Microfarad Ceramic
INDUCTORS	
L1	11-1/2 T
L2	11-1/2 T
L3	11-1/2 T
L4	11-1/2 T
L5	0.15 Microhenry

TABLE 2 - Continued

<u>PART NUMBER</u>	<u>PART DESCRIPTION</u>
INDUCTORS	
L6	11-1/2 T
L7	11-1/2 T
DIODES	
D1	1N914
D2	1N914
D3	1N914
D4	1N914
D5	1N914
D6	1N914
TRANSISTORS	
Q1	2N3904
Q2	2N3904
Q3	2N3904
Q4	2N3904
Q5	2N5179 Metal Can
Q6	2N5179 Metal Can
Q7	2N3904
Q8	2N3904
Q9	2N3904
Q10	2N3904
Q11	2N3904
Q12	2N5179 Metal Can
CRYSTALS	
Y1	19.3400 MHz Series Resonant Crystal
Y2	19.4467 MHz Series Resonant Crystal



TABLE 2 - Continued

<u>PART NUMBER</u>	<u>PART DESCRIPTION</u>
INTEGRATED CIRCUITS	
IC1	CA 3046 Transistor Array
IC2	CA 3046 Transistor Array
IC3	14175 4-Bit Latch

- (4) the signal spectrum was 65 dB below the carrier level at frequencies 40 kHz or more from the carrier frequency.

#### 4. The 19 MHz FSK Receiver

The operating requirements for the 19 MHz receiver are as follows:

- (1) a sensitivity of 0 dBmV,
- (2) a conducted spurious emission level of at least -50 dBmV,
- (3) an RF signal level sensing capability which is approximately "linear" over at least a  $\pm 10$  dB range centered on 0 dBmV, and
- (4) a squelch circuit capable of muting the receiver for incident signals.

Figure 3 presents the circuit which has been developed to serve as the 19 MHz receiver, and a parts list for this circuit is provided in Table 3.

The measured performance of the prototype circuit delivered to S/A was as follows:

- (1) sensitivity: -6 dBmV,
- (2) no spurious emissions were observable using the HP 1415/8553B/8552A spectrum analyzer assembly,
- (3) the measured characteristics of the RF level sensing circuit are presented in Figure 4. Note that the RF level adjustment allows the nominal signal level to be positioned in the "linear," as plotted, portion of this curve, and
- (4) a squelch circuit has been provided which can mute the receiver.

#### 5. The 107 MHz FSK Transmitter

The operating requirements for the 107 MHz transmitter are as follows:

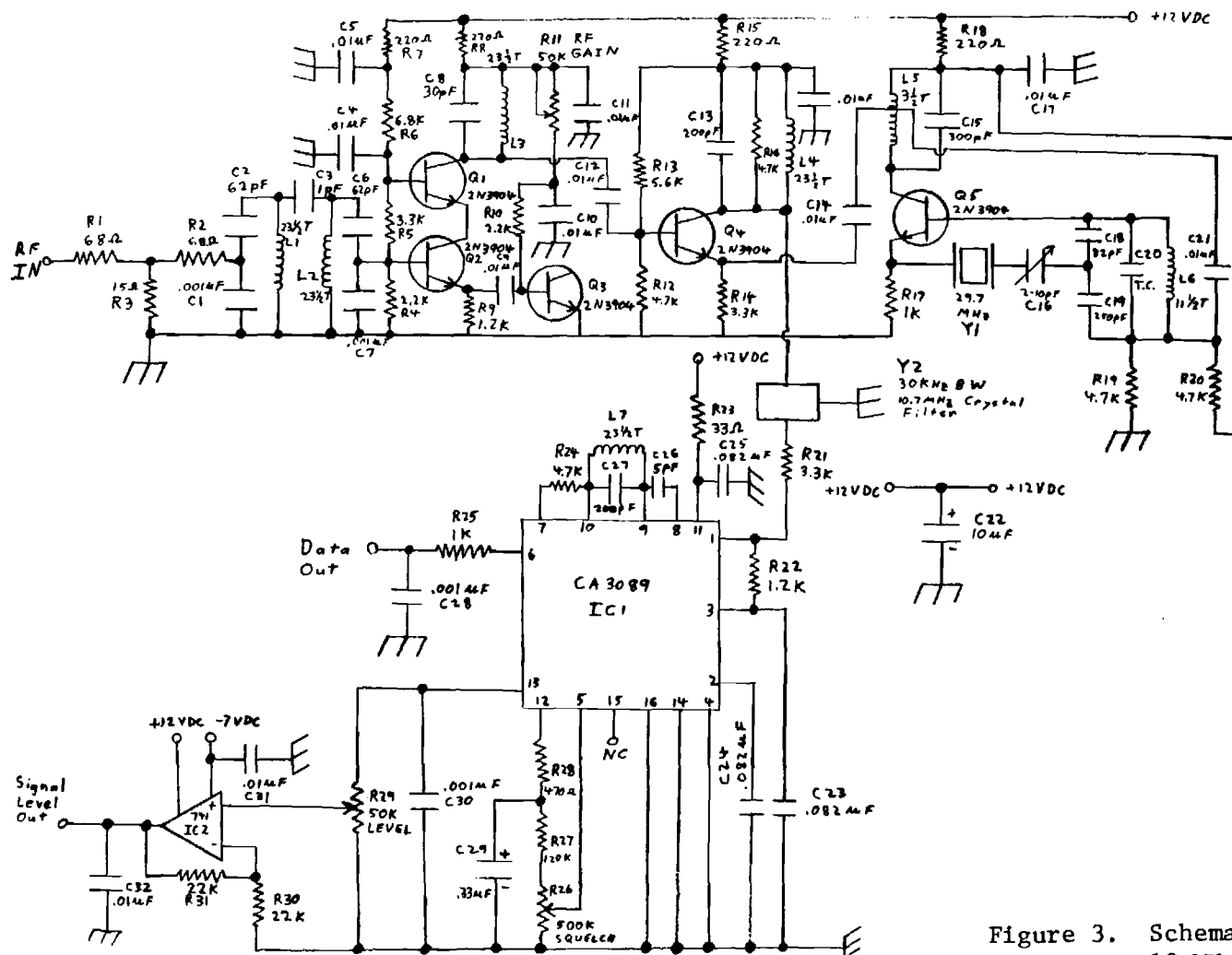


Figure 3. Schematic of  
19 MHz Receiver.

TABLE 3

## 19 MHz RECEIVER PARTS LIST

<u>PART NUMBER</u>	<u>PART DESCRIPTION</u>
RESISTORS (All Resistors are Carbon Film Type)	
R1	68 Ohm, 1/4W
R2	68 Ohm, 1/4W
R3	15 Ohm, 1/4W
R4	2.2 K, 1/4W
R5	3.3 K, 1/4W
R6	6.8 K, 1/4W
R7	220 Ohm, 1/4W
R8	220 Ohm, 1/4W
R9	1.2 K, 1/4W
R10	2.2 K, 1/4W
R11	50 K Potentiometer
R12	4.7 K, 1/4W
R13	5.6 K, 1/4W
R14	3.3 k, 1/4W
R15	220 Ohm, 1/4W
R16	4.7 K, 1/4W
R17	1 K, 1/4W
R18	220 Ohm, 1/4W
R19	4.7 K, 1/4W
R20	4.7 K, 1/4W
R21	3.3 K, 1/4W
R22	1.2 K, 1/4W
R23	33 Ohm, 1/4W
R24	4.7 K, 1/4W
R25	1 K, 1/4W
R26	500 K Potentiometer
R27	120 K, 1/4W
R28	470 Ohm, 1/4W

TABLE 3 - Continued

<u>PART NUMBER</u>	<u>PART DESCRIPTION</u>
RESISTORS	
R29	50 K Potentiometer
R30	22 K, 1/4W
R31	22 K, 1/4W
CAPACITORS (All Ceramic and Silver Mica are 50 VDC)	
C1	.001 Microfarad Ceramic
C2	62 pF Silver Mica
C3	1 pF Silver Mica
C4	.01 Microfarad Ceramic
C5	.01 Microfarad Ceramic
C6	62 pF Silver Mica
C7	.001 Microfarad Ceramic
C8	30 pF Silver Mica
C9	.01 Microfarad Ceramic
C10	.01 Microfarad Ceramic
C11	.01 Microfarad Ceramic
C12	.01 Microfarad Ceramic
C13	200 pF Silver Mica
C14	.01 Microfarad Ceramic
C15	300 pF Silver Mica
C16	2-10 pF Trimmer
C17	.01 Microfarad Ceramic
C18	82 pF Silver Mica
C19	250 pF Silver Mica
C20	Temperature Compensating
C21	.01 Microfarad Ceramic
C22	10 Microfarad Electrolytic, 25 WV DC
C23	.082 Microfarad Ceramic
C24	.082 Microfarad Ceramic

TABLE 3 - Continued

<u>PART NUMBER</u>	<u>PART DESCRIPTION</u>
CAPACITORS	
C25	.082 Microfarad Ceramic
C26	5 pF Silver Mica
C27	200 pf Silver Mica
C28	.001 Microfarad Ceramic
C29	.33 Microfarad Tantalum
C30	.001 Microfarad Ceramic
C31	.01 Microfarad Ceramic
C32	.01 Microfarad Ceramic
INDUCTORS	
L1	23-1/2 Turns
L2	23-1/2 Turns
L3	23-1/2 Turns
L4	23-1/2 Turns
L5	3-1/2 Turns Center Tap
L6	11-1/2 Turns
L7	23-1/2 Turns
TRANSISTORS	
Q1	2N3904
Q2	2N3904
Q3	2N3904
Q4	2N3904
Q5	2N3904
INTEGRATED CIRCUITS	
IC1	CA 3089
IC2	741

TABLE 3 - Continued

<u>PART NUMBER</u>	<u>PART DESCRIPTION</u>
	CRYSTALS
Y1	29.7 MHz Series Resonant Crystal
Y2	30 kHz BW 10.7 MHz Crystal Filter

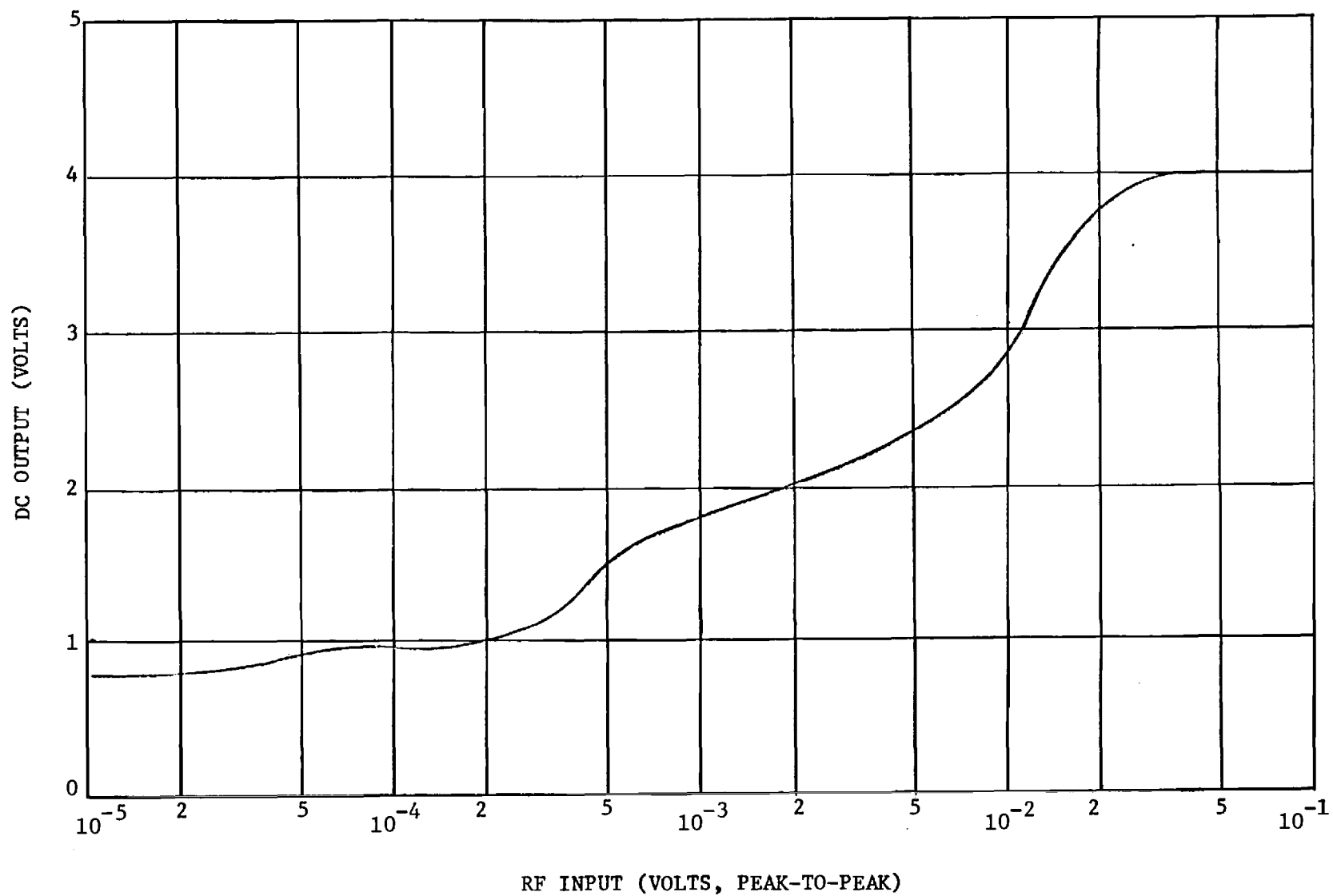


Figure 4. Typical RF Level Sensing Curve 19 MHz Receiver.



- (1) an output level of +60 dBmV,
- (2) a conducted spurious emission level 60 dB below the output of the transmitter, and
- (3) a signal bandwidth of 50 kHz (signal down at least 20 dB with respect to carrier level).

Figure 5 presents the circuit which has been developed to serve as the 107 MHz transmitter, and a parts list for this circuit is provided in Table 4.

The measured performance of the prototype circuit delivered to S/A was as follows:

- (1) output level: 59.6 dBmV
- (2) spurious emissions:
  - 58 dB below carrier at 86 MHz,
  - 55 dB below carrier at 75 MHz,
  - 56 dB below carrier at 64 MHz.
- (3) the signal's spectral components were 48 dB below the carrier at frequencies 50 kHz or more away from the center frequency of the signal.

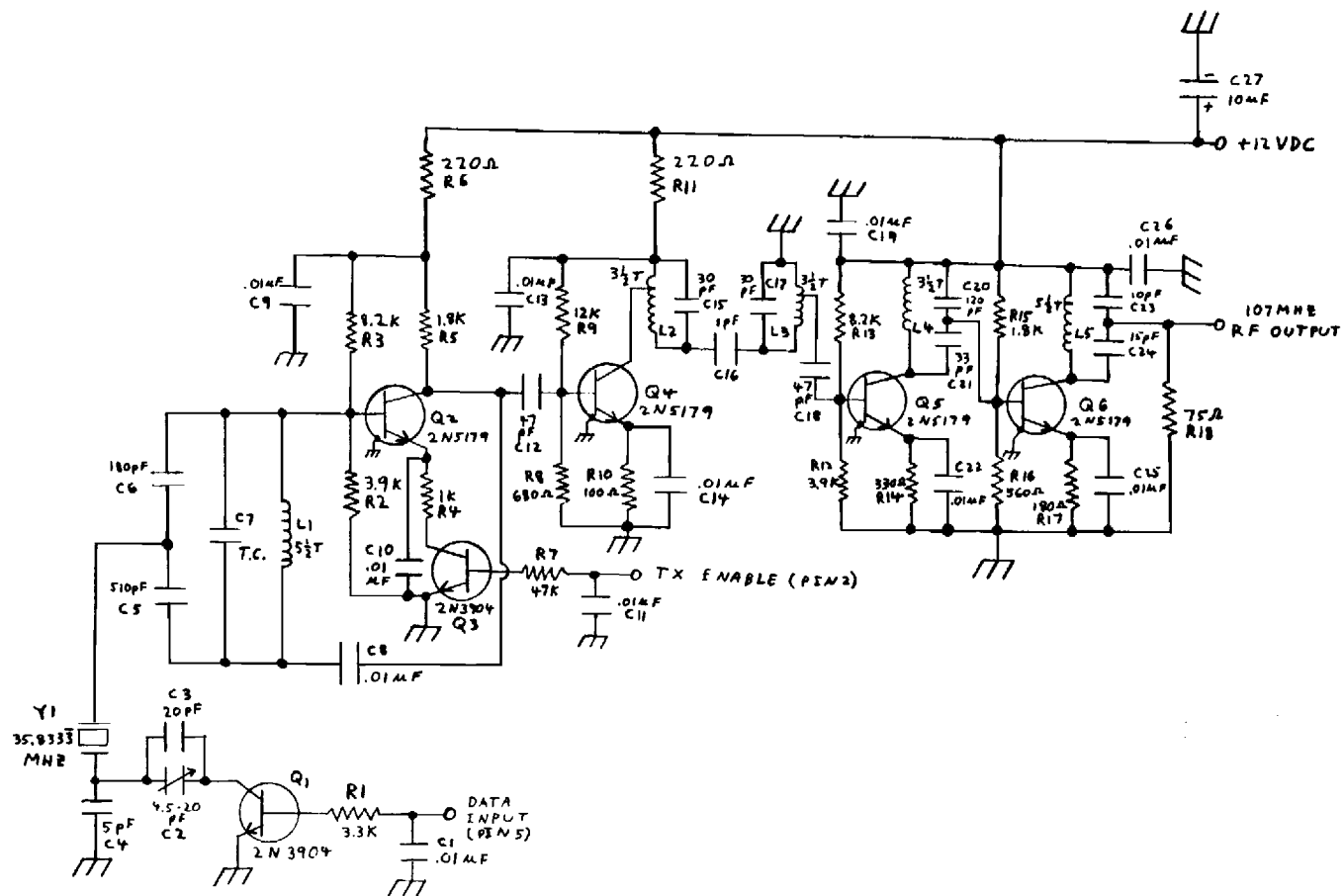


Figure 5. Schematic of 107 MHz Transmitter.

TABLE 4

## 19 MHz RECEIVER PARTS LIST

<u>PART NUMBER</u>	<u>PART DESCRIPTION</u>
RESISTORS (All Resistors are Carbon Film Type)	
R1	3.3 K, 1/4 W
R2	3.9 K, 1/4 W
R3	8.2 K, 1/4 W
R4	1 K, 1/4 W
R5	1.8 K, 1/4 W
R6	220 Ohm, 1/4 W
R7	47 K, 1/4 W
R8	680 Ohm, 1/4 W
R9	12 K, 1/4 W
R10	100 Ohm, 1/4 W
R11	220 Ohm, 1/4 W
R12	3.9 K, 1/4 W
R13	8.2 K, 1/4 W
R14	330 Ohm, 1/4 W
R15	1.8 K, 1/4 W
R16	560 Ohm, 1/4 W
R17	180 Ohm, 1/4 W
R18	75 Ohm, 1/4 W
CAPACITORS (All Ceramic and Silver Mica are 50 VDC)	
C1	.01 Microfarad Ceramic
C2	4.5-20 pF Trimmer
C3	20 pF Silver Mica
C4	5 pF Silver Mica
C5	510 pF Silver Mica
C6	180 pF Silver Mica
C7	Temperature Compensating
C8	.01 Microfarad Ceramic

Table 4 - Continued

<u>PART NUMBER</u>	<u>PART DESCRIPTION</u>
CAPACITORS (All Ceramic and Silver Mica are 50 VDC)	
C9	.01 Microfarad Ceramic
C10	.01 Microfarad Ceramic
C11	.01 Microfarad Ceramic
C12	47 pF Silver Mica
C13	.01 Microfarad Ceramic
C14	.01 Microfarad Ceramic
C15	30 pF Silver Mica
C16	1 pF Silver Mica
C17	30 pF Silver Mica
C18	47 pF Silver Mica
C19	.01 Microfarad Ceramic
C20	120 pF Silver Mica
C21	33 pF Silver Mica
C22	.01 Microfarad Ceramic
C23	10 pF Silver Mica
C24	15 pF Silver Mica
C25	.01 Microfarad Ceramic
C26	.01 Microfarad Ceramic
C27	10 Microfarad Electrolytic 25 WVDC
INDUCTORS	
L1	5-1/2 Turn
L2	3-1/2 Turn
L3	3-1/2 Turn
L4	3-1/2 Turn
L5	5-1/2 Turn

Table 4 - Continued

<u>PART NUMBER</u>		<u>PART DESCRIPTION</u>
	TRANSISTORS	
Q1		2N3904 Plastic Case
Q2		2N5179 Metal Case
Q3		2N3904 Plastic Case
Q4		2N5179 Metal Case
Q5		2N5179 Metal Case
Q6		2N5179 Metal Case
	CRYSTALS	
Y1		35.8333 MHz Series Resonant Crystal



AM AND FM BROADCAST COVERAGE  
ANALYSIS FOR DISTRIBUTION OF  
LAND MANAGEMENT SIGNALING BY  
SOUTHERN CALIFORNIA EDISON

By

R.W. Rice

April 1982

Prepared for

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Atlanta, Georgia

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***Georgia Institute of Technology***  
*A Unit of the University System of Georgia*  
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## 1. INTRODUCTION

This report provides an approximate analysis of the coverage that can be provided by both AM and FM broadcast stations in Southern California Edison's service area for the purpose of load management signaling. Due to time limitations, it was not possible to acquire the kind of detailed information which would permit a detailed coverage analysis, and the analysis has also been generalized with respect to the type of detection techniques used in the load management receiver. For AM stations, it is assumed that the signaling technique will be either a slow phase shift keying of the station's carrier or low deviation frequency shift keying. In either case, the frequency components associated with the data modulation are to be confined within a ten Hertz bandwidth centered on the carrier's nominal frequency.

The AM coverage analysis presented in Section 2 is based upon FCC procedures for evaluating ground wave coverage. At standard AM broadcast frequencies, terrain variations are of limited significance for ground wave coverage; therefore, the standard procedures should produce reasonably good results.

The FM coverage analysis presented in Section 3 is the free space loss modified to reflect the additional loss which may be expected due to diffraction losses associated with rough terrain. This analysis is approximate in nature. Should it be desired to produce more accurate results when time constraints are not so severe, this is readily possible using some of the well documented propagation models which relate, in a statistical fashion, the distribution of propagation losses to the statistics of terrain variation in the region of interest.

## 2. AM COVERAGE CALCULATIONS

The coverage provided by AM broadcast stations has two components: the ground-wave region and the sky-wave region. The latter tends to be highly variable with dramatic differences in daytime and evening coverage. This variability limits the utility of the extended coverage provided by the sky-wave propagation, and therefore, the analysis presented here addresses only the ground-wave coverage.

Included in the Federal Communications Commission's Rules and Regulations, Part 73, are curves which may be used to predict the ground-wave coverage of AM broadcast stations. Three pieces of information are necessary to utilize these curves:

- (1) the soil conductivity in the vicinity of the AM radio station,
- (2) the radiation effectiveness of the station's antenna system, and
- (3) the licensed transmitter power of the station.

Data on soil conductivity is readily available, and for Southern California, the conductivity varies between four millimhos/meter in the desert regions and 15 millimhos in the coastal regions. For this analysis, an average soil conductivity of eight millimhos/meter has been assumed.

By far, the most common form of antenna used by AM broadcast stations is the vertical, and the radiation efficiency of these antennas varies over a range of approximately 1.5:1 for heights ranging from 0.05 wavelengths to 0.6 wavelengths. Given the constraints of practical tower heights, it is assumed that the typical tower will be approximately 0.2 wavelengths (about 200 ft for a frequency of 1000 kHz). For such an antenna, the radiated field at one mile is approximately 200 mV/m per kilowatt of input power. This means that the field intensities for the

postulated typical antenna are twice those predicted by the FCC curves which assume a field intensity of 100 mV/m at one mile for one kilowatt of input power.

In defining the extent of AM coverage, one must address issues such as receiver sensitivity and ambient noise level. To an extent, the FCC has addressed this issue by defining field intensities required to constitute primary service in various environments. The required field intensities are defined below.

<u>Environment</u>	<u>Required Field Intensity</u>
Urban, industrial	10-50 mV/meter
Urban, residential	2-10 mV/meter
Rural	0.1-1.0 mV/meter

In the analysis that follows, the upper limit of field intensity has been used for each environment category.

It should be pointed out that these required field intensities as defined by the FCC apply to the conventional AM signal as received by a non-coherent detector. The PSK and FSK techniques being considered for load management signaling have extremely narrow bandwidths when compared to the information bandwidth of the AM signal; therefore, the required field intensity for reliable detection of the load management signal will most likely be significantly below that required for the reliable detection of the AM signal itself.

Table 1 identifies AM broadcast stations which can provide coverage to the major population centers in Southern California Edison's service area subject to the assumptions identified above. Figures 1, 2, and 3 show the coverage areas on the map of the Southern California region.

TABLE 1  
CONTOUR RANGES FOR AM BROADCAST STATIONS

<u>AREA: STATION</u>	<u>ERP</u>	<u>CONTOUR RANGE</u>		
		<u>50 mV/METER</u>	<u>10 mV/METER</u>	<u>1 mV/METER</u>
LOS ANGELES: KMPC	50 kW, day 10 kW, night	55 mi. 23	110 mi. 54	240 mi. 140
VISALIA: KMJ KCHJ	5 kW 5 kW, day 1 kW, night	15 12 3	46 26 12	135 72 36
SANTA BARBARA: KTMS KOXR	1 kW 5 kW, day 1 kW, night	3 12 3	8 30 11	28 82 41
SAN BERNARDINO: KPRO	1 kW	3	7	24
PALM SPRINGS: KDES	5 kW, day 0.5 kW, night	11.5 1.5	28.5 7	76 28.5
BARSTOW: KWTC	1 kW, day 0.25 kW, night	3 0.8	9 3	29 15.5
LANCASTER: KAVL	1 kW, day 0.5 kW, night	3 2	15 7	63 43
VICTORVILLE: KAVR	5 kW, day	11.5	29	78



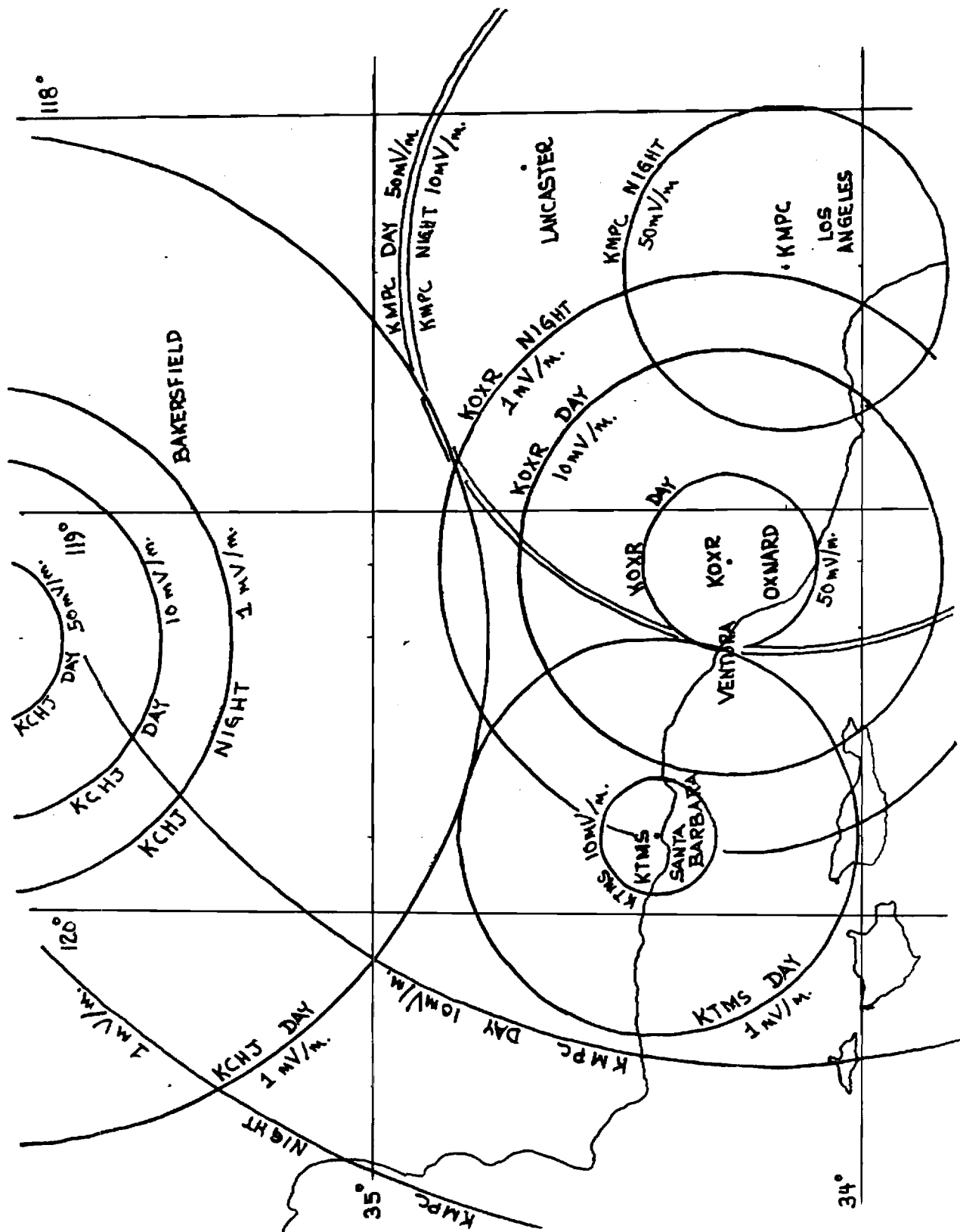


Figure 2. AM broadcast coverage in the Santa Barbara area.

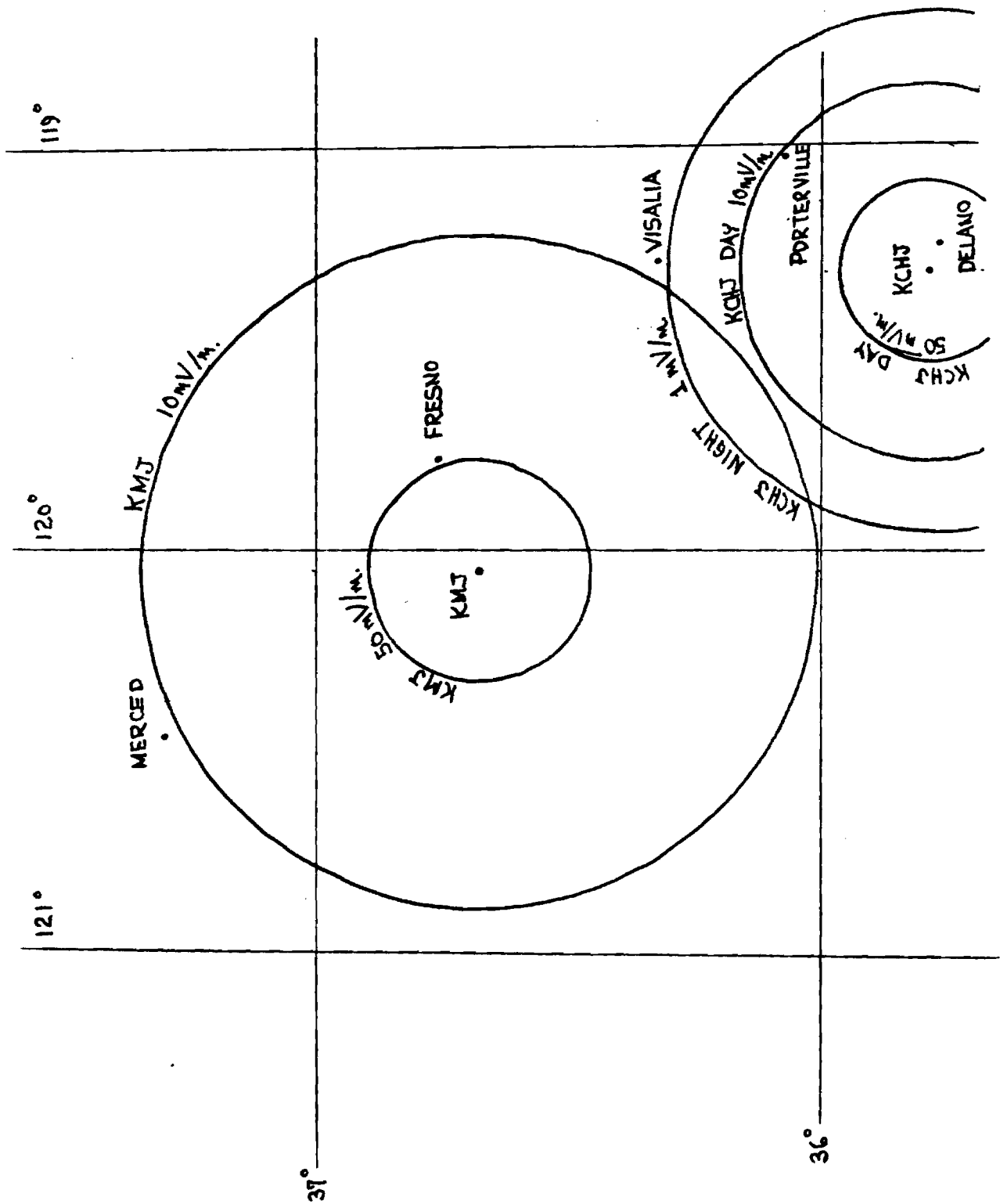


Figure 3. AM broadcast coverage in the San Joaquin Valley area.

### 3. FM COVERAGE CALCULATIONS

The process of evaluating the ability to provide load management (LM) commands by broadcast FM SCA involves two steps:

- (1) Evaluate the maximum allowable propagation attenuation, and
- (2) Define the coverage contours based upon data specific to actual FM broadcast stations in the utility's service area.

The ability to accurately decode an LM instruction depends upon having a reasonable signal-to-noise-ratio (SNR) at the output of the receiver's demodulator. In this application the noise level will be influenced principally by the ambient noise level which is a mixture of both natural and man-made noise. Empirical data shows that for a bandwidth of 200 kHz at an operating frequency of 100 MHz, the ambient noise level varies between -81 dBm for urban environments to -96 dBm for suburban environments.

The typical form of FM demodulation employed for applications of this type is frequency discrimination, and for this form of demodulation, the threshold of "full-improvement" occurs at an input SNR of 12 dB. It is assumed that an additional 3 dB of input SNR will assure that the LM signal is decoded reliably; and therefore, the minimum required signal levels are -66 dBm (1.8 mV/m) for an urban environment and -81 dBm (0.31 mV/m) for a suburban environment.

The evaluation of coverage contours for this application has used a simplified technique to permit an approximate analysis to be performed rapidly with only limited amounts of information. The propagation attenuation calculations are based upon a combination of the free space losses and the losses associated with a single knife edge diffraction. The latter component is divided into three categories:



- (1) The case where the height of the diffraction edge is small compared with the height of the transmitting antenna,
- (2) The case where the height of the diffraction edge is comparable to the height of the transmitting antenna, and
- (3) The case where the height of the diffraction edge is large compared with the height of the transmitting antenna.

Table 2 shows the pertinent data for various FM stations in the service area of Southern California Edison. Figures 4, 5, and 6 show predicted coverage contours for various stations providing coverage to the majority of the populated areas of this part of the state. The contours shown correspond to the following:

<u>SITE</u>	<u>STATION</u>	<u>CONTOUR</u>
A	KHAY KACY	A1 A2
B	KBIG	B1
C	KOTE	C1
D	KVVQ	D1
E	KWTC	E1
F	KONG	F1
G	KDES	G1

The coverage patterns shown assume that the receiving antenna is an isotropic antenna positioned three feet above ground level.

TABLE 2  
FM BROADCAST STATION DATA

<u>CITY: STATION</u>	<u>FREQUENCY (MHz)</u>	<u>ERP (WATTS)</u>	<u>TOWER ELEV(HAAT)</u>	<u>LONGITUDE DEG/MIN/SEC</u>	<u>LATITUDE DEG/MIN/SEC</u>
LOS ANGELES:					
KBIG	104.3	105	2890	118/03/59	34/13/36
KNX	93.1	54	3010	118/04/18	34/13/57
KLOS	95.5	68	2920	118/03/59	34/13/36
KFAC	92.3	39	2910	118/03/57	34/13/36
KRTH	101.1	58	2880	118/04/00	34/13/38
KMET	94.7	58	2830	118/03/47	34/13/29
KPFB	90.7	110	2830	118/03/57	34/13/36
SANTA BARBARA:					
KRUZ	103.3	105	2980	119/57/10	34/31/30
KTMS	97.5	16	2900	119/57/28	34/31/32
KTYB	99.9	34	550	119/40/33	34/28/15
VENTURA:					
KHAY	100.7	39	1210	119/19/57	34/20/55
OXNARD:					
KACY	104.7	2.85	1580	119/20/07	34/20/59
VICTORVILLE:					
KVVQ	103.1	0.095	1430	117/17/31	34/36/45
VISALIA:					
KONG	92.9	15.5	950	119/05/15	36/17/10
BARSTOW:					
KWTC	94.3	3	-193	117/01/39	34/54/44

TABLE 2 (Continued)

LONG BEACH:

KNOB	97.9	79	410	118/09/46	33/47/54
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SAN BERNARDINO:

KOLA	99.9	31	1630	117/16/59	33/57/55
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SANTA ANA:

KWIZ	96.7	3	120	117/54/36	33/45/06
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KYMS	106.3	3	130	117/51/17	33/45/21
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RIVERSIDE:

KDUP	97.5	68	1570	117/17/21	33/57/57
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PALM SPRINGS:

KDES	104.7	42	540	116/26/04	33/51/56
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LANCASTER:

KOTE	106.3	3	135	118/07/30	34/44/41
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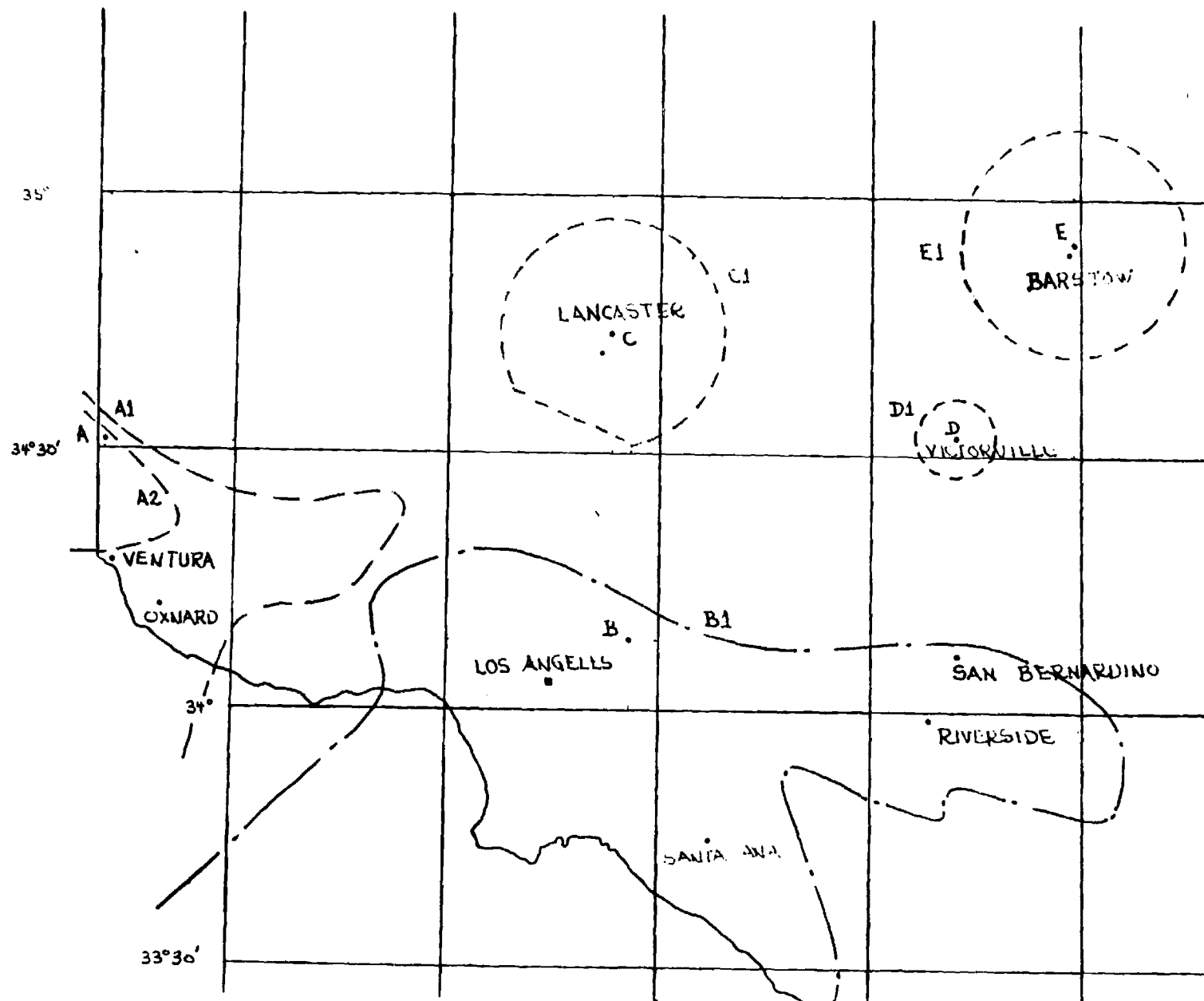


Figure 4. FM coverage in the Los Angeles area.

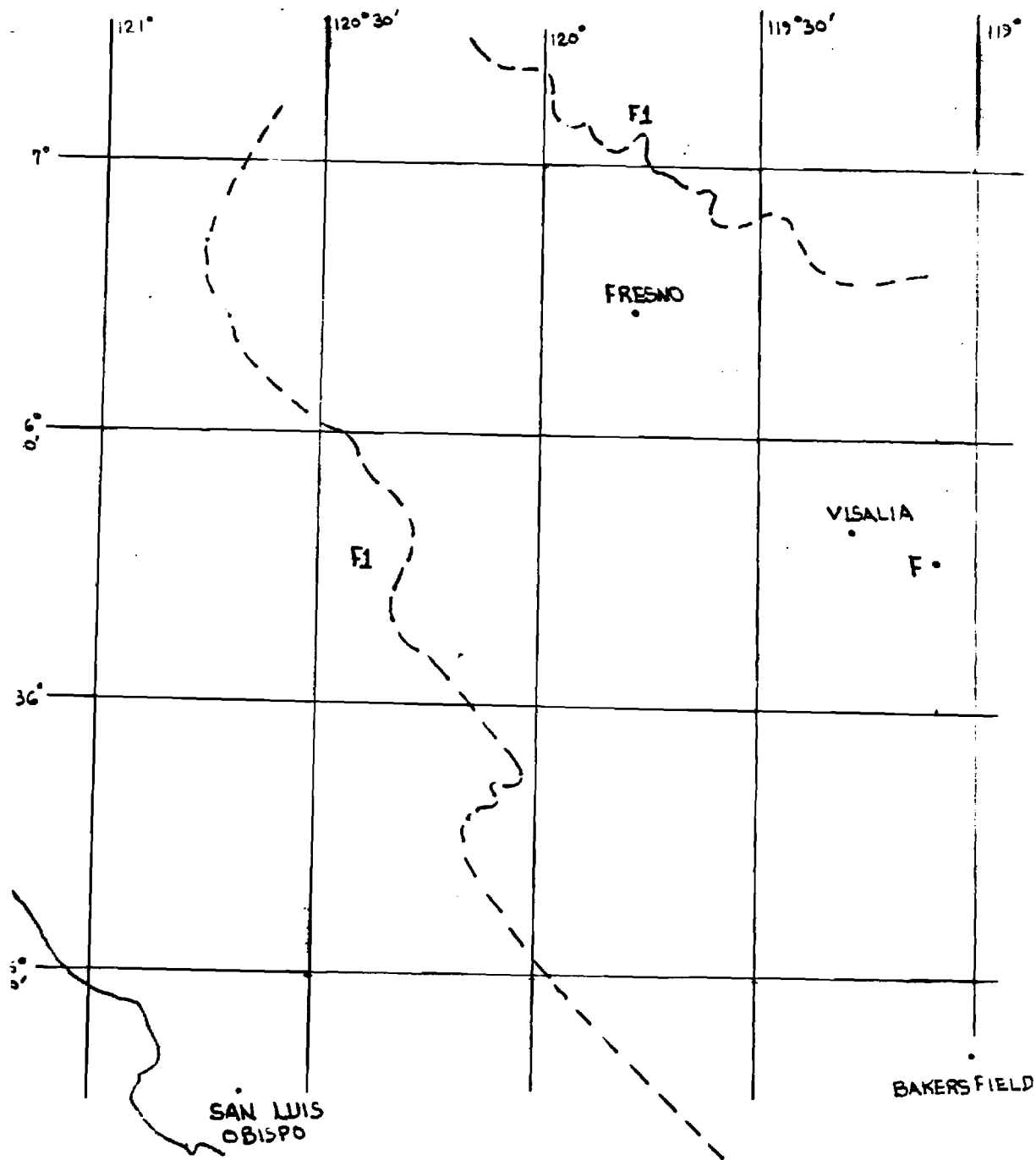


Figure 5. FM coverage in the San Joaquin Valley.

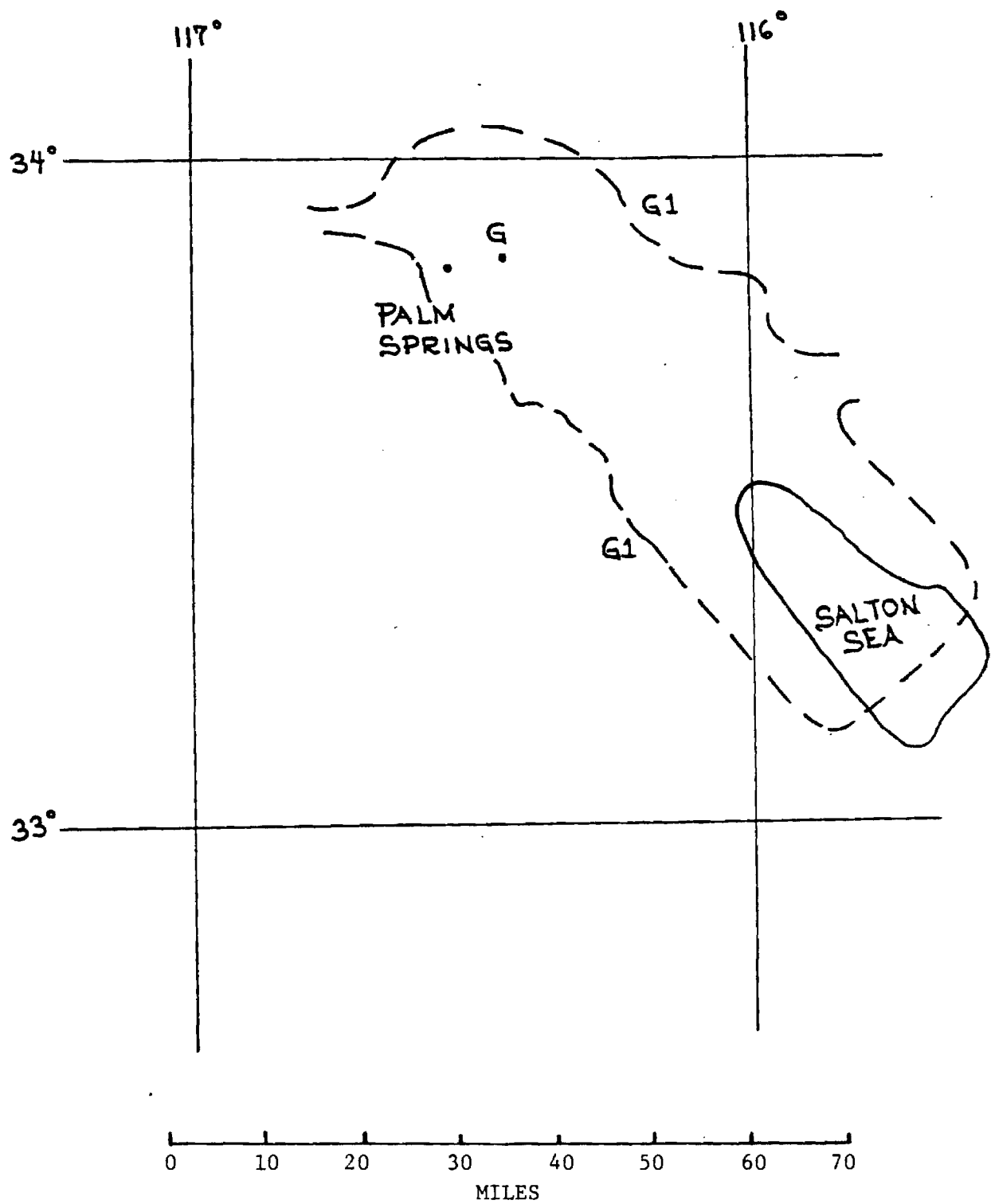


Figure 6. FM coverage in the Palm Springs area.